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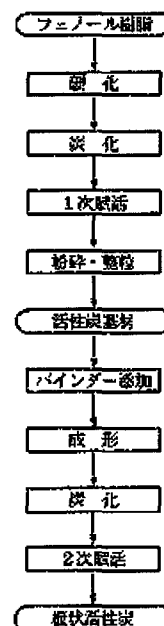
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(54) 【発明の名称】 電気二重層コンデンサー用活性炭電極の製造方法及び活性炭電極

(57) 【要約】

【目的】 大きな板状に成形可能な機械的強度を有し、かつ大電流放電が可能な電気二重層コンデンサー用として好適な活性炭電極を提供することを目的としている。

【構成】 本発明の電気二重層コンデンサー用活性炭電極の製造方法は、炭素化合物を炭化処理して得られた炭化物に、1次賦活処理を施して炭素基材とし、該炭素基材にバインダーを加えて成形体とし、該成形体を炭化処理した後、2次賦活処理を施す。



PATENT ABSTRACTS OF JAPAN

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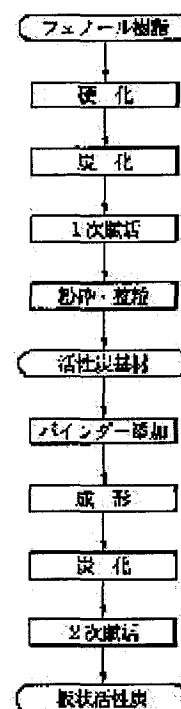
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(54) ACTIVE CARBON ELECTRODE OF ELECTRONIC DOUBLE-LAYER CAPACITOR AND MANUFACTURE THEREOF

(57)Abstract:

PURPOSE: To stably obtain an active carbon electrode which is high in electrostatic capacitance and quality by a method wherein a carbide is subjected to a primary activation treatment to serve as a carbon material, binder is added to the carbon material, the binder-loaded carbon material is molded, and the molded body is subjected to a carbonization treatment and then to a secondary activation treatment.

CONSTITUTION: Novolak phenolic resin is cured and then ground into particles prescribed in size, the resin particles are carbonized by a thermal treatment carried out in a nitrogen atmosphere. In succession, the carbonized particles are thermally treated into granular activated carbon material in a carbon dioxide gas atmosphere through a primary activation treatment. The granular activated carbon material is ground into powder, and phenolic resin, ethanol, and creosote are mixed as binder into the activated carbon powder, which is kneaded well and molded into a plate-like piece. The



molded plate-like piece is subjected to a carbonization treatment in a nitrogen atmosphere, and thermally treated into a plate-like activated carbon in a carbon dioxide gas atmosphere through a secondary activation treatment. By this setup, an active carbon electrode high in electrostatic capacitance and quality can be stably obtained.

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TECHNICAL FIELD

[Industrial Application] This invention relates to the manufacture approach of the activated carbon electrode suitably used as an electric double layer capacitor, and the activated carbon electrode obtained by that cause.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] This invention relates to the manufacture approach of the activated carbon electrode suitably used as an electric double layer capacitor, and the activated carbon electrode obtained by that cause.

[0002]

[Description of the Prior Art] The electric double layer capacitor is used as a power source for backup of electronic equipment, such as a personal computer, and development is performed also as an object for high current supply for auxiliary power at the moments, such as an auxiliary dc-battery of an automobile. The electrode of this electric double layer capacitor is called a polarizable electrode, and it is required that it should have big electrostatic capacity. Therefore, the conductive carbon material with a large specific surface area as an ingredient of a polarizable electrode is used, and activated carbon [finishing / especially activation] is desirable. As an activated carbon base material [finishing / activation], there is a fibrous thing with it being powdered.

[0003] Various pyrolysis nature carbon compounds, such as thermosetting resin, such as phenol resin, are used for manufacture of activated carbon as a raw material from the thing of carbonaceous, such as corks, coal, and coconut shell charcoal. Drawing 6 a is the outline of the activated carbon production process which used phenol resin as the raw material. As shown in this drawing, after hardening phenol resin first, activation is carried out through the carbonization process which it distills [process] dryly and volatilizes components other than carbon, it carries out grinding and a particle size regulation if needed, and powder thru/or a granular activated carbon base material are obtained. In addition, the method of obtaining a fibrous activated carbon base material through processes, such as carbonization processing, is learned similarly, using an acrylic fiber etc. for a carbon compound raw material, and maintaining a fiber configuration.

[0004] Although said powder thru/or a granular activated carbon base material were mixed with the sulfuric-acid solution to the polarizable electrode of an electric double layer capacitor and it was conventionally used for it as the shape of a paste, the contact resistance between active charcoal children was large, and was not able to pass a big current. Moreover, when fibrous activated carbon cloth was used, similarly, the contact resistance between fiber and the activated carbon consistency per unit volume were small, and a high current was not able to be acquired.

[0005] Then, as shown in drawing 6 b, it carbonizes similarly, the binder which added, fabricated and added the binder to the activated carbon base material further is sintered, and how to use as a tabular Plastic solid can be considered. Although the pyrolysis nature carbon compound which serves as the same carbonaceous as a base material after carbonization is chosen as a binder, the same phenol resin as a raw material is desirable in this case. Also when fibrous activated carbon is used for a base material, the space

between fiber is embedded with a binder, if it carbonizes similarly and sinters, it becomes tabular [with a large consistency] and the use as a polarizable electrode can be expected. [0006]

[Problem(s) to be Solved by the Invention] However, the activated carbon polarizable electrode for electric double layer capacitors which carbonized and sintered [added and] the binder and obtained it to the above conventional activated carbon base materials having un-arranged [that the electrostatic capacity per the weight often becomes lower than a base material]. Activation is not not only carried out, but about that cause, the carbonaceous component which the added binder carbonized and generated is guessed whether the activity of a base material is checked by this carbonaceous component by a certain reason in the above-mentioned conventional approach. Then, although it tried to perform activation processing finally after not carrying out activation but adding and fabricating a binder to the activated carbon powder of non-activation before obtaining an activated carbon base material as shown in drawing 6 c, the thing of sufficient mechanical strength was not obtained, but the crack occurred at the time of activation processing, and shaping was difficult. Furthermore, it did not improve, so that electrostatic capacity was also expected. Since the activated carbon electrode produced by said conventional approach as mentioned above has the weak mechanical strength, the actual condition is that the tabular big thing suitable for high current discharge is not obtained.

[0007] This invention was made in view of said situation, and aims at having the mechanical strength which can be fabricated to tabular [big], and offering an activated carbon electrode suitable as an object for electric double layer capacitors in which high current discharge is possible.

[0008]

[Means for Solving the Problem] After the manufacture approach of the activated carbon electrode for electric double layer capacitors of this invention performs primary activation processing to the carbide obtained by carrying out carbonization processing of the carbon compound, uses it as a carbon base material, adds a binder to this carbon base material, uses it as a Plastic solid and carries out carbonization processing of this Plastic solid, it is characterized by performing secondary activation processing.

[0009] Phenol resin is suitable although all can use a coconut shell, wood quality, coal, a pitch, naturally-occurring polymers, synthetic macromolecule, etc. for said carbon compound. Moreover, as said binder, what dissolved phenol resin powder in oleophilic liquids, such as organic solvents, such as ketones, such as alcohols, and an acetone, a cyclohexanone, creosote oil, a coal tar, anthracene oil, kerosene, a liquid paraffin, ethylene glycol, and a glycerol, can be used.

[0010] Here, if it is heat-treating an ingredient in carbon dioxide gas or a steam ambient atmosphere and is in this invention, it sets to secondary activation processing, and activation processing is a degree type (i).

Activation yield =(weight before weight / activation processing after activation processing) x100 (i)

It is characterized by choosing the temperature and time amount of heat treatment so that the activation yield of the secondary activation processing which is alike and is obtained more may become 75% or more. Furthermore, it is a degree type (ii).

Comprehensive activation yield = activation yield /100 of activation yield x activation

[secondary] processing of primary activation processing (ii)

It is characterized by the comprehensive activation yield which is alike and is obtained more being 70 - 95%.

[0011] Moreover, it is characterized by this activated carbon electrode that manufactured the activated carbon electrode for the electric double layer capacitors of this invention by said approach having the specific surface area of 600-1500m²/g.

[0012]

[Function] After fabricating an activated carbon base material [finishing / activation] in a tabular electrode configuration using binders, such as phenol resin, as for the activated carbon Plastic solid by the conventional approach (drawing 6 b) of carbonizing a binder etc., the activity may fall from that of a base material. As shown in drawing 6 c on the other hand, when activation is not carried out in the production process of the activated carbon of a base material but activation is carried out at once after sintering, the moldability to a tabular Plastic solid is bad.

[0013] Then, as the activated carbon electrode for electric double layer capacitors is not obtained but is shown in drawing 1 , after fabricating the activated carbon base material which carried out activation (primary activation) beforehand in a tabular electrode configuration using a binder only by 1 time of activation, the binder etc. was carbonized and it solved that it was indispensable to carry out activation (secondary activation) again after that in order to obtain the activated carbon electrode for electric double layer capacitors. Furthermore, as a result of repeating trial-and-error and carrying out investigation variously about the conditions of activation, activation yield found out that they were requirements very important not only for a moldability but electrostatic capacity.

[0014] First, in secondary activation processing, the effect the activation processing yield shown by the above-mentioned formula (i) affects a moldability is large, and if the value is not 75% or more, it cannot fabricate in a good electrode configuration. Moreover, the value of electrostatic capacity with it is acquired by choosing the temperature and time amount of heat treatment so that the comprehensive activation yield which is the product of the primary activation yield [secondary] may serve as range which is 70 - 95%. [high and electrostatic-capacity and] [stable] Furthermore, when specific surface area is the range which is 600-1500m²/g, the activated carbon electrode of stable and high electrostatic capacity is obtained.

[0015] Therefore, in the production process of the above-mentioned activated carbon electrode, by managing the above-mentioned activation yield and specific surface area, it excels in a moldability and a quality activated carbon electrode with high electrostatic capacity can be obtained to stability.

[0016]

[Example] An example explains this invention to a detail further. According to the production process shown in drawing 1 , the activated carbon electrode was manufactured by using phenol resin as a raw material. In the following examples 1 and 2, an example 1 investigates the effectiveness of activation processing in a carbon-dioxide-gas ambient atmosphere, and an example 2 investigates the effectiveness of activation processing in a steam ambient atmosphere. Experiment (1)-in example 1 - (11) changes the temperature and time amount of the primary secondary activation processing, and investigates the effect. Moreover, experiment (12) - (14) compares the result of having

not performed secondary activation processing and having not performed primary activation processing in an experiment (15).

[0017] Example 1: An activation experiment in a carbon-dioxide-gas ambient atmosphere (1)

After hardening novolak mold phenol resin at 160 degrees C, it crushed on about 2mm square. This was heat-treated at 900 degrees C among nitrogen gas for 30 minutes, and it carbonized. Then, among carbon dioxide gas, it heat-treated for 1 hour, primary activation was carried out at 900 degrees C, and the granular-active-carbon base material of specific-surface-area of 650m²/g was obtained. Primary activation yield (weight in front of the weight/activation after = activation) was 92%.

[0018] This granular-active-carbon base material was ground, the phenol resin 15 weight section, the ethanol 8 weight section, and the creosote 20 weight section were added and kneaded as a binder to this powder 100 weight section as powder of 8 micrometers of mean diameters, and it pressed by the pressure of 500kg/cm², and considered as the tabular Plastic solid of 50x50x1 (mm).

[0019] In nitrogen gas, the temperature up was carried out to 900 degrees C with the programming rate of 100 degrees C/h, and it held for 30 minutes and carbonization processing was carried out, and succeedingly, among carbon dioxide gas, the acquired Plastic solid was heat-treated for 10 hours, and carried out secondary activation at 800 degrees C. The activation yield at that time (= weight in front of the weight/activation after activation) was 93%. Therefore, comprehensive activation yield becomes 0.92x0.93x100=86%. As a result of measuring the BET specific surface area of the acquired Plastic solid, it was 740m²/g.

[0020] By secondary activation processing, since there was neither curvature nor generating of a crack in a Plastic solid, two disks of 14mmphi (1mm in thickness) were cut down, the cel for measurement which a 30wt% sulfuric-acid solution is infiltrated in a vacuum, and is shown in drawing 2 was produced, and electrostatic capacity was calculated after this. For a sign 1, as for a gasket and 3, an activated carbon electrode and 2 are [a collector and 4] separators among drawing 2 . Generally, electrostatic capacity C can discharge with the fixed current I after charge, can measure time amount Δt which falls from an electrical potential difference V₁ to V₂, and can ask for it by the bottom type (iii).

$C = I \times \Delta t / (V_2 - V_1) \dots (iii)$

Here, it discharged by 4 mA/cm² after 24-hour charge by 900mV, and discharged by 400 mA/cm² after 2-hour charge succeedingly. And all obtained 26 F/cm³ as V₁=540mV and V₂=360mV at the time of 61 F/cm³, 400 mA/cm² at the time of 4 mA/cm², respectively.

[0021] Experiment (2) - (11)

The temperature and time amount of the primary secondary activation processing in an experiment (1) were changed, and the effect on those moldabilities and electrostatic capacity was investigated. It hung up over Table 1 collectively also including the result of an experiment (1).

[0022] Experiment (12)

Carbonization processing of the Plastic solid acquired in the experiment (1) was carried out on the same conditions as an experiment (1), and secondary activation processing was not carried out, but two disks of 14mmphi (1mm in thickness) were cut down as they were, and electrostatic capacity was measured like the experiment (1). The result was

hung up over Table 1.

[0023] Experiment (13)

Electrostatic capacity was measured like the experiment (12) except having made time amount of primary activation into 2 hours. The result was hung up over Table 1.

[0024] Experiment (14)

Electrostatic capacity was measured like the experiment (12) except having made time amount of primary activation into 3 hours. The result was hung up over Table 1.

[0025] Experiment (15)

Except having not performed primary activation, like the experiment (1), the activated carbon electrode was obtained and electrostatic capacity was measured. The result was hung up over Table 1.

[0026]

[Table 1]

1次および2次賦活処理とも炭酸ガス雰囲気中

実験 番号	1次賦活処理			2次賦活処理			比表面積 m ² /g	総合 収率 %	成形性	静電容量 F/c m ³	
	温度	時間	収率	温度	時間	収率				4mA/cm ²	400mA/cm ²
	℃	h	%	℃	h	%					
(1)	900	1	92	800	10	93	740	86	良好	61	26
(2)	"	1	"	"	20	84	1080	77	"	59	25
(3)	"	2	80	"	20	83	1770	66	"	50	17
(4)	"	1	95	"	31	76	1370	72	"	59	25
(5)	"	1	95	900	2.5	75	1450	71	"	58	24
(6)	"	1	95	"	2.6	73	1700	67	割れあり	—	—
(7)	"	2.5	75	800	20	84	1950	63	良好	43	10
(8)	"	2.7	72	"	10	93	1650	68	"	52	20
(9)	800	1	99	"	1	99	550	98	"	45	9
(10)	"	1	99	"	2	98	570	97	"	51	16
(11)	"	2	98	"	4	97	600	95	"	57	24
(12)	"	1	92	—	—	—	—	—	"	49	16
(13)	"	2	80	—	—	—	—	—	"	50	17
(14)	"	3	70	—	—	—	—	—	"	48	15
(15)	—	—	—	900	2.3	74	—	—	割れあり、モロイ	—	—

[0027] In the above-mentioned table 1, experiment (1) - (11) carries out the primary secondary activation which is indispensable requirements in this invention approach, and is changing those conditions. First, a fall of the activation yield observed the inclination for a tabular moldability to worsen, about secondary activation. In an experiment (4) and (5), secondary activation yield is 76% and 75%, respectively, and very few curvatures of extent which does not interfere practically were accepted. In an experiment (6), secondary activation yield became 73%, curvature and a crack occurred, and a tabular Plastic solid was not acquired. Although secondary activation yield can fabricate at less than 75% in a tabular electrode configuration from the above thing, it turns out that moldability sufficient at 75% or more is not obtained. Furthermore, primary activation is not performed, the crack occurred and the experiment (15) was not able to be easily fabricated to tabular.

[0028] Although fabricated by the tabular electrode configuration, electrostatic capacity is shown in drawing 3 as a function of a total yield. In this drawing, although the point connected with the continuous line performs primary secondary activation and the total yield shows high electrostatic capacity in 70 - 95% of range as for current 4 mA/cm² and 400 mA/cm², electrostatic capacity is falling at less than 70% and 95% or more. On the other hand, the point connected with the broken line is not performing secondary activation, and electrostatic capacity is low (experiment (12) - (14)).

[0029] Example 2: In the activation example 2 in the inside of a steam ambient atmosphere, primary secondary activation processing was performed in the steam ambient atmosphere according to the production process shown in drawing 1 . Experiment (16) - (22) changes the temperature and time amount of the primary secondary activation processing, and investigates the effect. On the other hand, experiment (23) - (24) compares the result of having not performed secondary activation processing.

[0030] Experiment (16)

Novolak mold phenol resin was hardened [as well as the experiment (1)] and carbonized. Then, among the steam ambient atmosphere, it heat-treated for 3.5 hours, primary activation was carried out at 800 degrees C, and the granular-active-carbon base material of specific-surface-area of 620m²/g was obtained. Primary activation yield was 94%.

[0031] The above-mentioned granular-active-carbon base material was ground to 8 micrometers of mean diameters, and like the experiment 1, carbonization was performed, after adding and fabricating the binder and acquiring a good Plastic solid. Succeedingly, among the steam ambient atmosphere, at 800 degrees C, it heat-treated for 9 hours and activation was carried out. Activation yield was 85%. Therefore, comprehensive activation yield becomes $0.94 \times 0.85 \times 100 = 80\%$. As a result of measuring BET surface area, it was 970m²/g. Moreover, as a result of measuring electrostatic capacity like an experiment (1), it was 22 F/cm³ at the time of 58 F/cm³, 400 mA/cm² at the time of 4 mA/cm².

[0032] Experiment (17) - (22)

The temperature and time amount of the primary secondary activation processing in an experiment (16) were changed, and the effect on those moldabilities and electrostatic capacity was investigated. The result was hung up over Table 2 together with the result of an experiment (16).

[0033] Experiment (23) - (24)

Changing the conditions in the primary activation in the inside of a steam ambient atmosphere, secondary activation did not carry out but made others be the same as that of an experiment (16). Since the tabular moldability was good, electrostatic capacity was measured and the result was hung up over Table 2.

[0034]

[Table 2]

1次および2次賦活処理とも炭酸ガス雰囲気中

実験 番号	1次賦活処理			2次賦活処理			比表面積 m ² /g	総合 収率 %	成形性	静電容量 F/cm ³	
	温度	時間	収率	温度	時間	収率				4mA/cm ²	400mA/cm ²
	℃	h	%	℃	h	%					
(16)	800	3.5	94	800	9	85	970	80	良好	58	22
(17)	"	2	97	"	2	97	620	94	"	56	21
(18)	"	5	92	"	15.5	76	1500	70	"	55	20
(19)	750	2	98	750	1	99	570	97	"	37	11
(20)	800	10	83	800	15	76	1920	63	"	39	7
(21)	"	5	92	"	15.5	74	1620	68	割、割あり	—	—
(22)	750	5	95	"	16.5	72	—	68	割、割あり	—	—
(23)	800	8.5	89	—	—	—	—	—	良好	50	14
(24)	"	16	73	—	—	—	—	—	"	49	13

[0035] In the above-mentioned table 2, experiment (16) - (22) carries out the primary secondary activation which is indispensable requirements in this invention approach, and is changing those conditions. First, a fall of the activation yield observed the inclination for a tabular moldability to worsen, about secondary activation. In the experiment (21) which secondary activation yield has not reached to 74%, 72%, and 75%, and (22), it turns out that curvature and a crack occur, a tabular Plastic solid is not acquired, and moldability sufficient at less than 75% is not obtained.

[0036] Next, although were fabricated by the tabular electrode configuration and electrostatic capacity with a total yield high in 70 - 95% of range is shown for current 4 mA/cm² and 400 mA/cm² by the point which shows electrostatic capacity in drawing 4 as a function of comprehensive activation yield of having connected with the continuous line in this drawing performing primary secondary activation, electrostatic capacity is falling at less than 70% and 95% or more. On the other hand, the point connected with the broken line is not performing secondary activation, and is understood that electrostatic capacity is lower (experiment (23) - (24)) than a previous thing.

[0037] Moreover, as shown in drawing 5, it has the relation of becoming small as the total yield of a BET specific surface area increases. The BET specific surface area corresponding to the range of 70 - 95% of total yields which it is same also in a steam and show a good property also when an activation processing ambient atmosphere is carbon dioxide gas was 1600m²/g from 600.

[0038]

[Effect of the Invention] As explained above, the activated carbon electrode by this invention carries out primary activation of the carbide obtained by hardening and carbonizing a carbon compound, obtains an activated carbon base material, adds and fabricates a binder to this, and gives and manufactures secondary activation succeedingly. And in this invention, it can fabricate to tabular [which was suitable for the electrode by choosing temperature and time amount / good], and the activated carbon electrode of specific surface area [****] is obtained so that the activation yield of the primary secondary activation may become a specific value, and the outstanding electrode for electric double layer capacitors with big electrostatic capacity is obtained.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] Drawing 1 is process drawing showing an example of the manufacture approach of the activated carbon electrode of this invention.

[Drawing 2] Drawing 2 is the sectional view of the activated carbon electrode produced in the example of this invention.

[Drawing 3] Drawing 3 is a graph which shows the result of the example of this invention and shows the relation of the electrostatic capacity of an activated carbon electrode and activation yield which were manufactured by carbon-dioxide-gas activation.

[Drawing 4] Drawing 4 is a graph which shows the result of the example of this invention and shows the relation of the electrostatic capacity of an activated carbon electrode and activation yield which were manufactured by steam activation.

[Drawing 5] Drawing 5 is a graph which shows the result of the example of this invention and shows the relation of the electrostatic capacity of an activated carbon electrode and the BET specific surface area which were manufactured.

[Drawing 6] Drawing 6 is drawing explaining the production process of conventional activated carbon and an activated carbon electrode.

[Description of Notations]

1 [.. Separator] An activated carbon electrode, 2 .. A gasket, 3 .. A collector, 4

WRITTEN AMENDMENT

----- [a procedure revision]

[Filing Date] September 20, Heisei 6

[Procedure amendment 1]

[Document to be Amended] Specification

[Item(s) to be Amended] 0020

[Method of Amendment] Modification

[Proposed Amendment]

[0020] By secondary activation processing, since there was neither curvature nor generating of a crack in a Plastic solid, two disks of 14mmphi (1mm in thickness) were cut down, the cel for measurement which a 30wt% sulfuric-acid solution is infiltrated in a vacuum, and is shown in drawing 2 was produced, and electrostatic capacity was calculated after this. For a sign 1, as for a gasket and 3, an activated carbon electrode and 2 are [a collector and 4] separators among drawing 2 . Generally, electrostatic capacity C can discharge with the fixed current I after charge, can measure time amount t which falls from an electrical potential difference V_1 to V_2 , and can ask for it by the bottom type (iii).

$C = I \cdot t / (V_1 - V_2)$ (iii)

Here, it discharged by 4 mA/cm² after 24-hour charge by 900mV, and discharged by 400 mA/cm² after 2-hour charge succeedingly. And all obtained 26 F/cm³ as $V_1 = 540\text{mV}$ and $V_2 = 360\text{mV}$ at the time of 61 F/cm³, 400 mA/cm² at the time of 4 mV/cm², respectively.

CLAIMS

[Claim(s)]

[Claim 1] The manufacture approach of the activated carbon electrode for electric double

layer capacitors characterized by performing primary activation processing to the carbide obtained by carrying out carbonization processing of the carbon compound, and performing secondary activation processing after considering as a carbon base material, adding a binder to this carbon base material, considering as a Plastic solid and carrying out carbonization processing of this Plastic solid.

[Claim 2] The manufacture approach of the activated carbon electrode for electric double layer capacitors of claim 1 characterized by a carbon compound being phenol resin.

[Claim 3] The manufacture approach of the activated carbon electrode for electric double layer capacitors of claims 1 or 2 characterized by being the constituent with which a binder consists of phenol resin powder, an organic solvent, and an oleophilic liquid.

[Claim 4] Primary activation processing and secondary activation processing are heat treatments in a carbon-dioxide-gas ambient atmosphere or a steam ambient atmosphere, and are a degree type (i).

Activation yield = (weight before weight / activation processing after activation processing) x 100 (i)

The manufacture approach of one activated carbon electrode for electric double layer capacitors of claims 1-3 characterized by the activation yield in the secondary activation processing which is alike and is obtained more being 75% or more.

[Claim 5] Primary activation processing and secondary activation processing are heat treatments in a carbon-dioxide-gas ambient atmosphere or a steam ambient atmosphere, and are a degree type (ii).

Comprehensive activation yield = activation yield / 100 of activation yield x activation [secondary] processing of primary activation processing (ii)

The manufacture approach of one activated carbon electrode for electric double layer capacitors of claims 1-3 characterized by the comprehensive activation yield which is alike and is obtained more being 70 - 95%.

[Claim 6] The activated carbon electrode for electric double layer capacitors which is manufactured from claim 1 by the manufacture approach of the activated carbon electrode for electric double layer capacitors given in five, and is characterized by specific surface area being 600-1500m²/g.